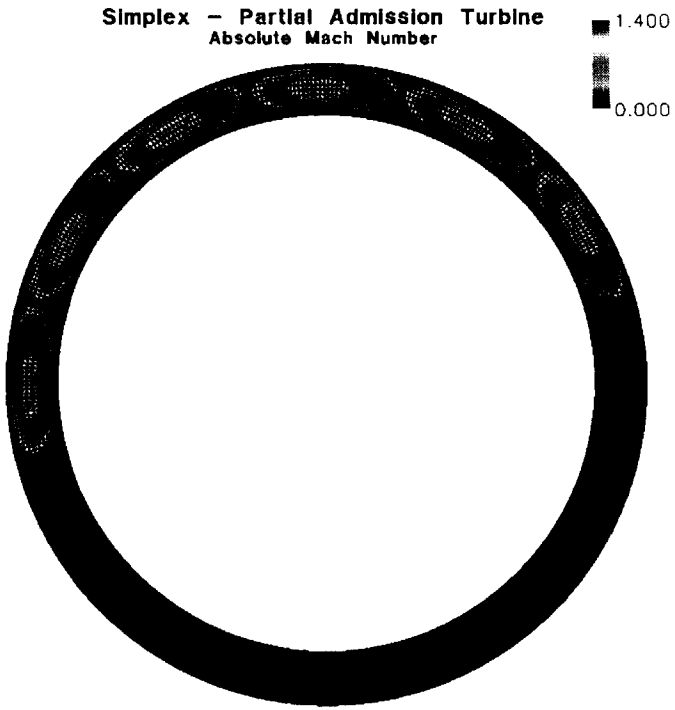
Simplex Turbine Full and Partial Admission Performance



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Outline

- **Motivation**
- **Flow code description - CORSAIR**
  - Capabilities
  - Future directions
- **Results**
  - Full admission
  - Partial admission
- **Conclusions**

Motivation

- **Determine the effects of partial admission flow on:**
  - rotor performance as a function of circumferential location
  - unsteady rotor loading
- **Provide an efficient technique for determining turbine performance**

Flow Code Capabilities - I

- **CORSAIR**
  - Unsteady time-dependent equations of motion
  - Full Navier-Stokes, thin-layer Navier-Stokes or Euler
  - Variable fluid properties (Cp, gamma)
- **Third-order spatial discretization of inviscid fluxes**
  - Roe
- **Second-order spatial discretization of viscous fluxes**
  - Standard central differences
- **Second-order temporal accuracy**
- **Multi-block O-H grid topology**
  - O-grids around airfoils and in tip clearance regions
  - H-grids for remainder of flow field and nozzles
  - Well-suited for medium-grain parallel simulations

Flow Code Capabilities - II

- **Turbulence models**
  - Highly-modified Baldwin-Lomax model
- **Transition models**
  - Abu-Ghannam and Shaw (natural)
  - Mayle (natural)
  - Modified Roberts' correlation (bubble)
- **Boundary conditions**
  - Steady and unsteady inlet and exit
  - Specified wall temperature or heat flux
  - Film cooling/mass injection
  - Symmetry
  - Actuator disk
  - Component linking
- **Grid Motion**
  - Arbitrary translation/rotation
  - Blade vibration

Flow Code Capabilities - III

- **MPI used for parallel simulations**
  - decomposition by blade row
  - decomposition by blade passage
  - decomposition by O- and H-grids
  - decomposition by component
  - user specified decomposition
- **Graphical User Interface**
  - Grid generation
  - Flow solver
  - Error checking
  - Design page
  - User's manual/help facility
  - Post-processing
- **Miscellaneous capabilities**
  - Conjugate heat transfer capability
  - Provides unsteady pressure file for stress analysis
  - Provide Fourier decomposition of unsteady pressures
  - Will run on any Unix, Linux or Windows NT platform

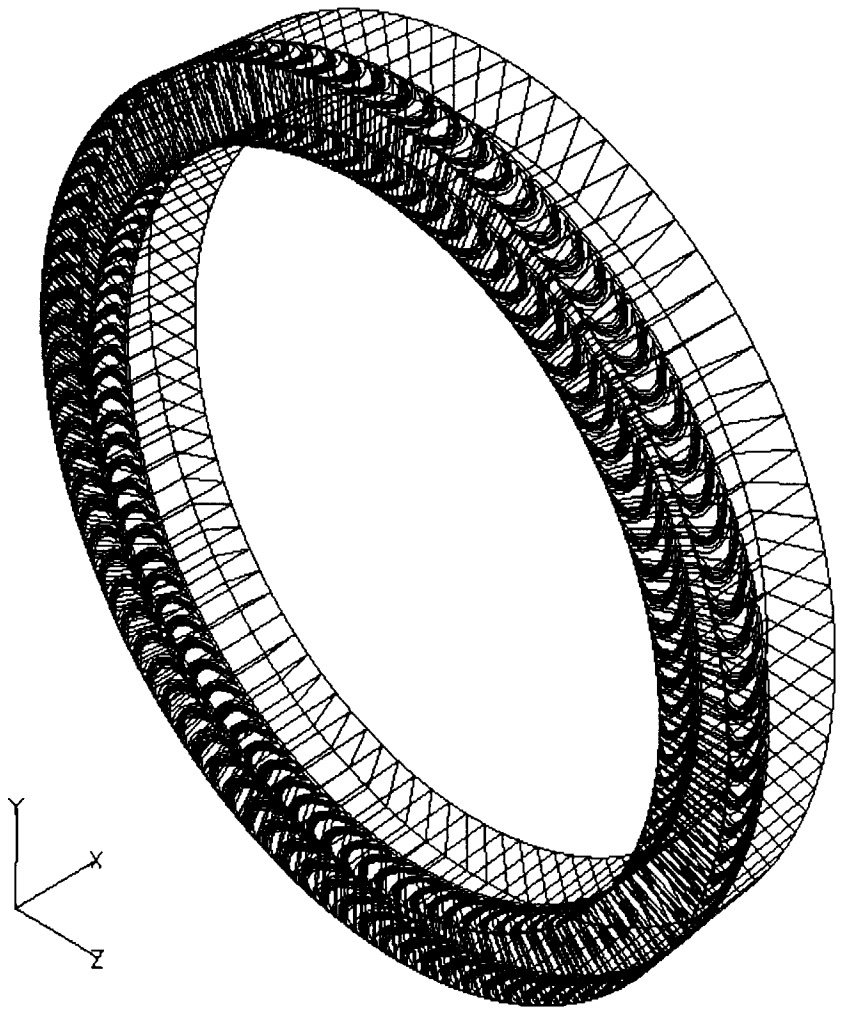
CORSAIR Future Directions

- **Dynamic memory allocation (being tested)**
- **Generalized, automated domain decomposition for MPI (being tested)**
- **Modify code for pump geometries**
  - incorporating incompressible flow physics
- **Incorporate two-phase flow modeling**
- **Incorporate cavitation modeling**

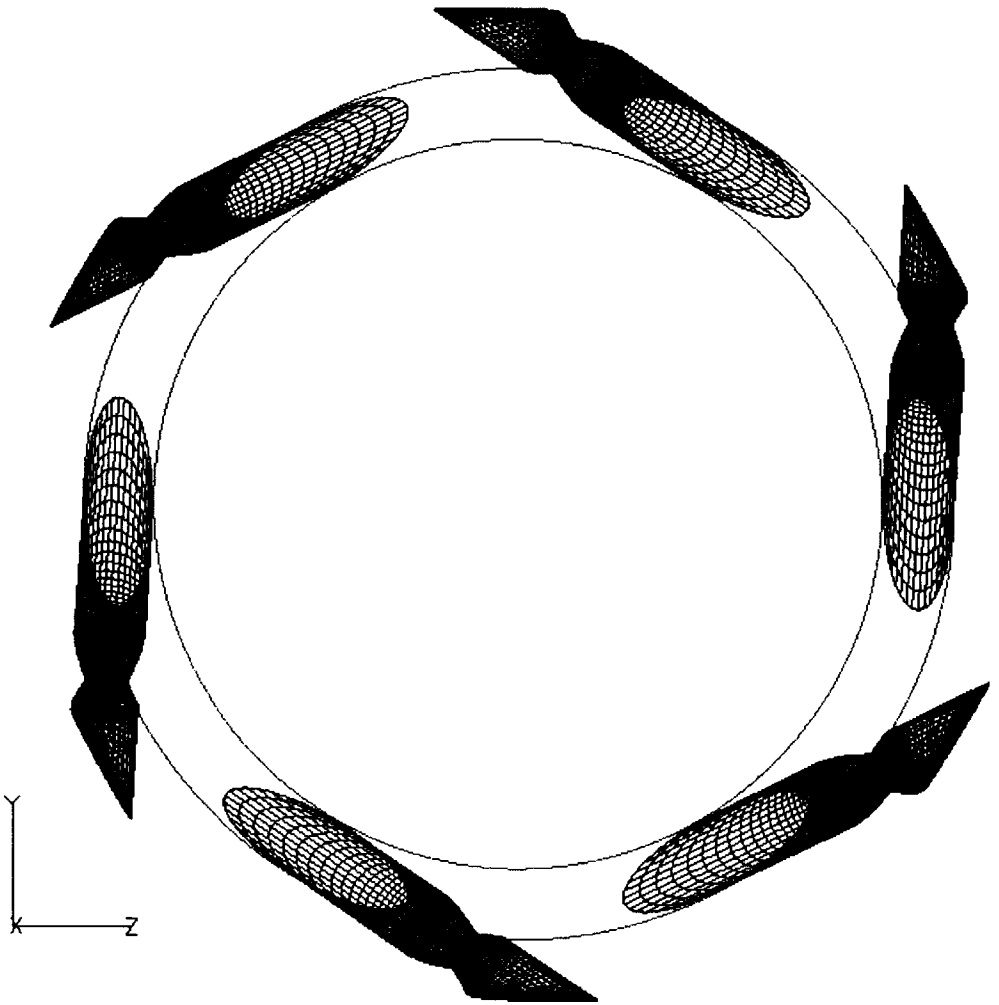
Simplex Turbine Simulations

- **Objective - determine the effects of partial admission on the rotor unsteady load and performance as a function of circumferential location**
- **Full-Admission simulation**
  - 1 nozzle and 8 rotors modeled
  - 750,000 grid points
  - 8 full cycles (one complete rotor revolution) completed
- **Partial-Admission simulation**
  - 6 nozzles and 95 rotors modeled
  - 7 million grid points
  - simulation in progress

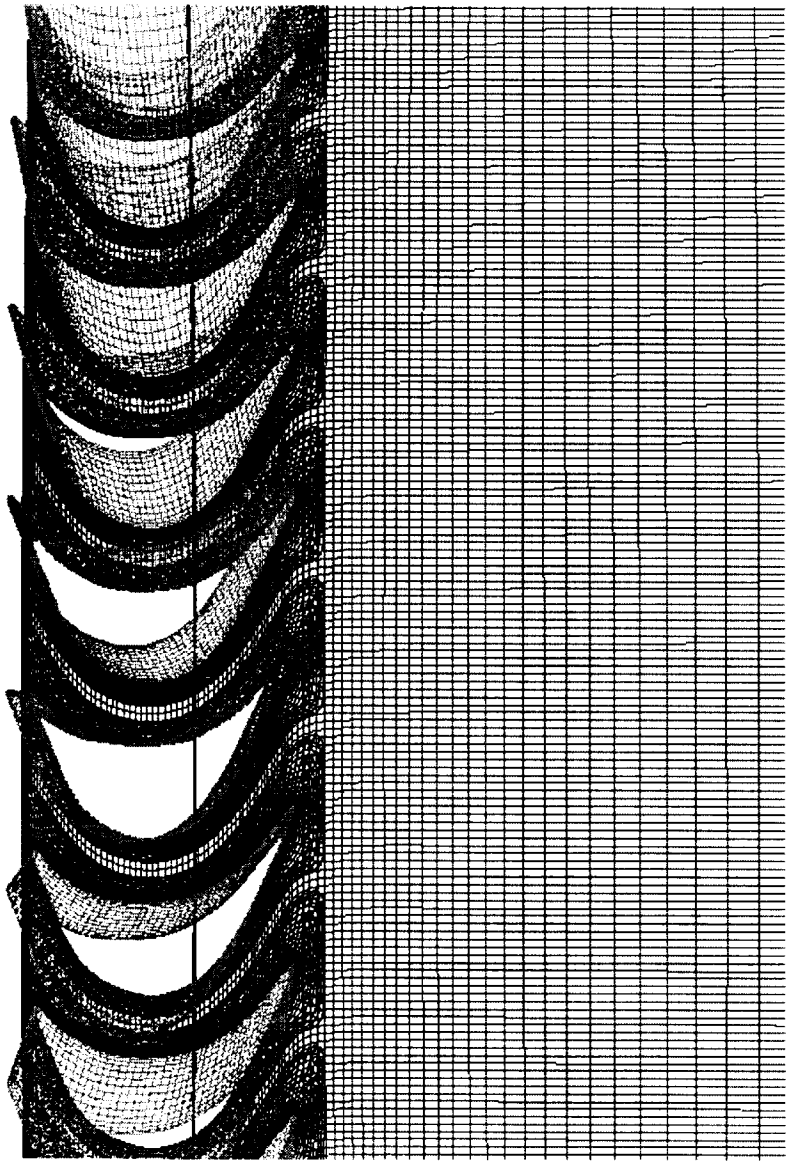
Simplex Turbine Rotors



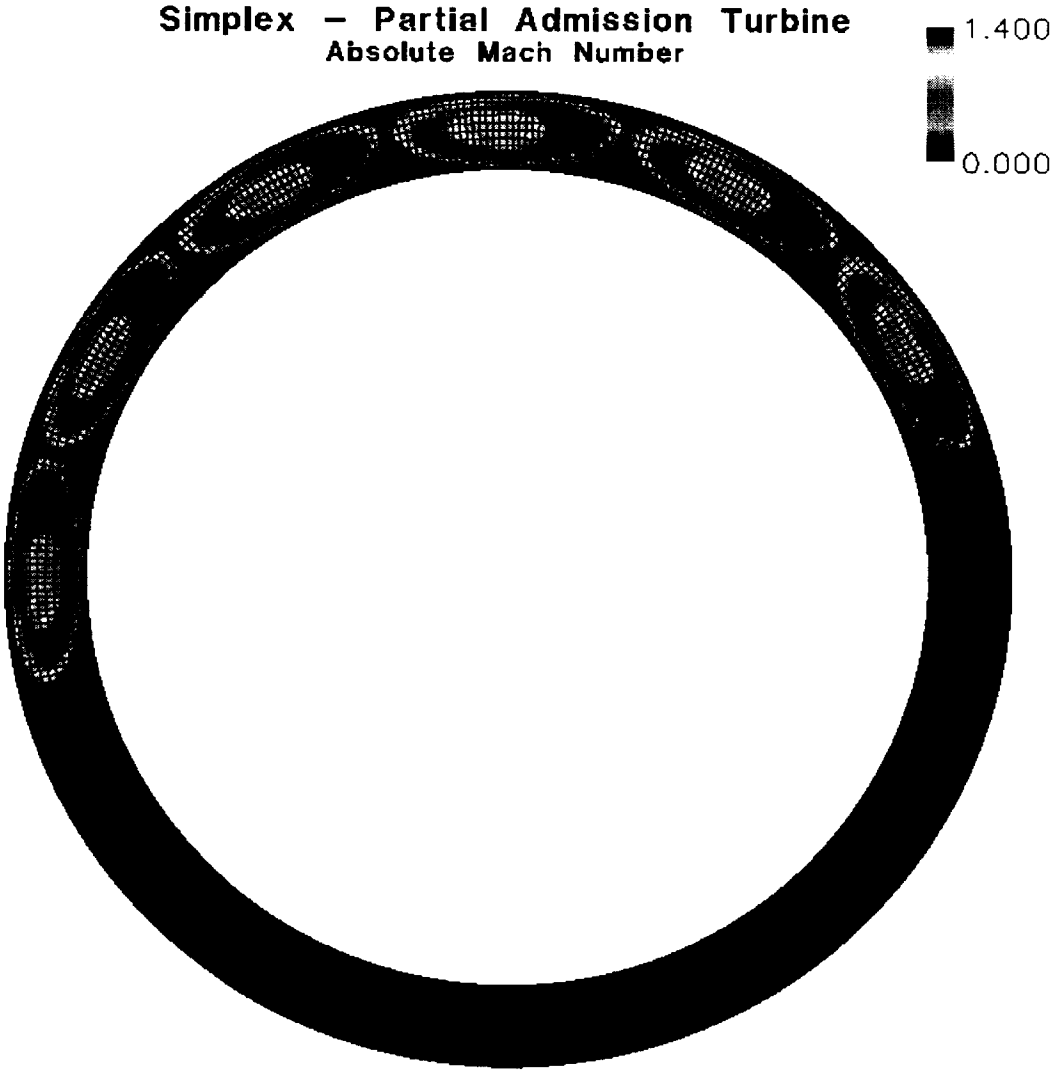
Simplex Turbine Nozzles



Computational Grids - Rotor

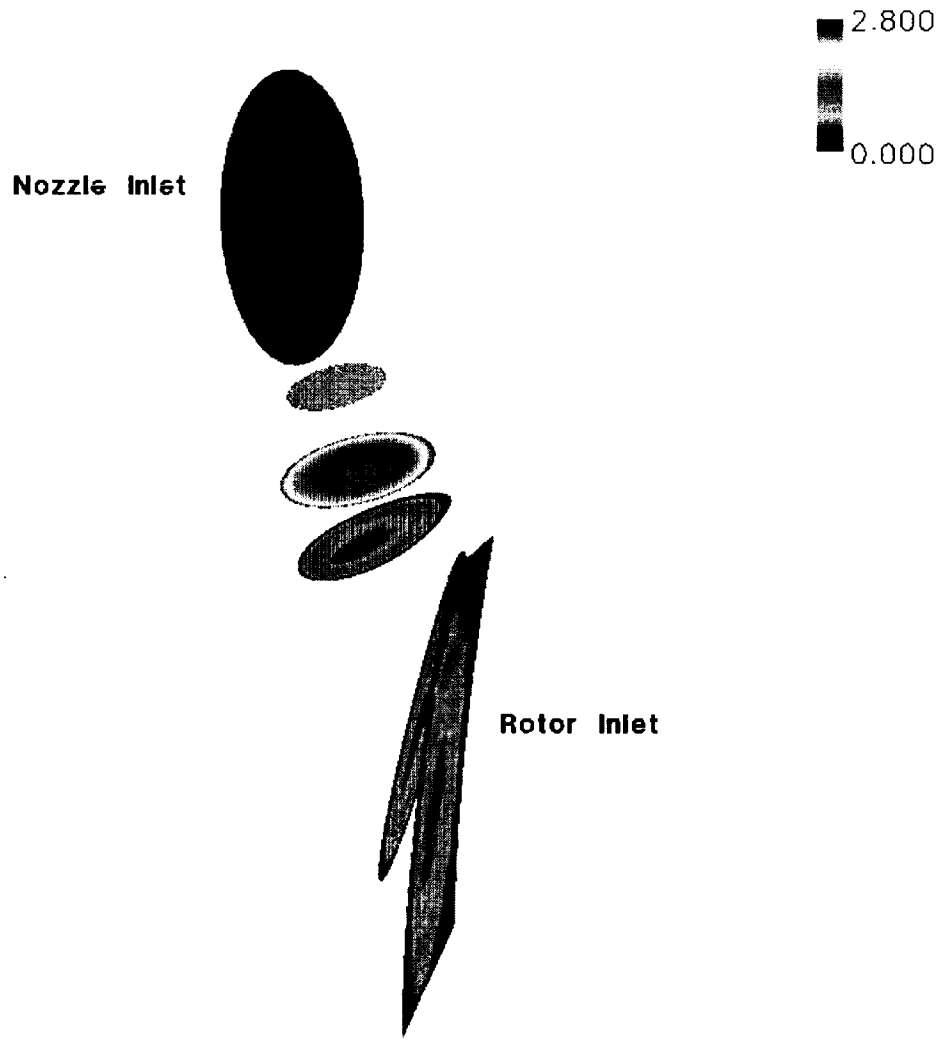


Nozzle/Rotor Interface

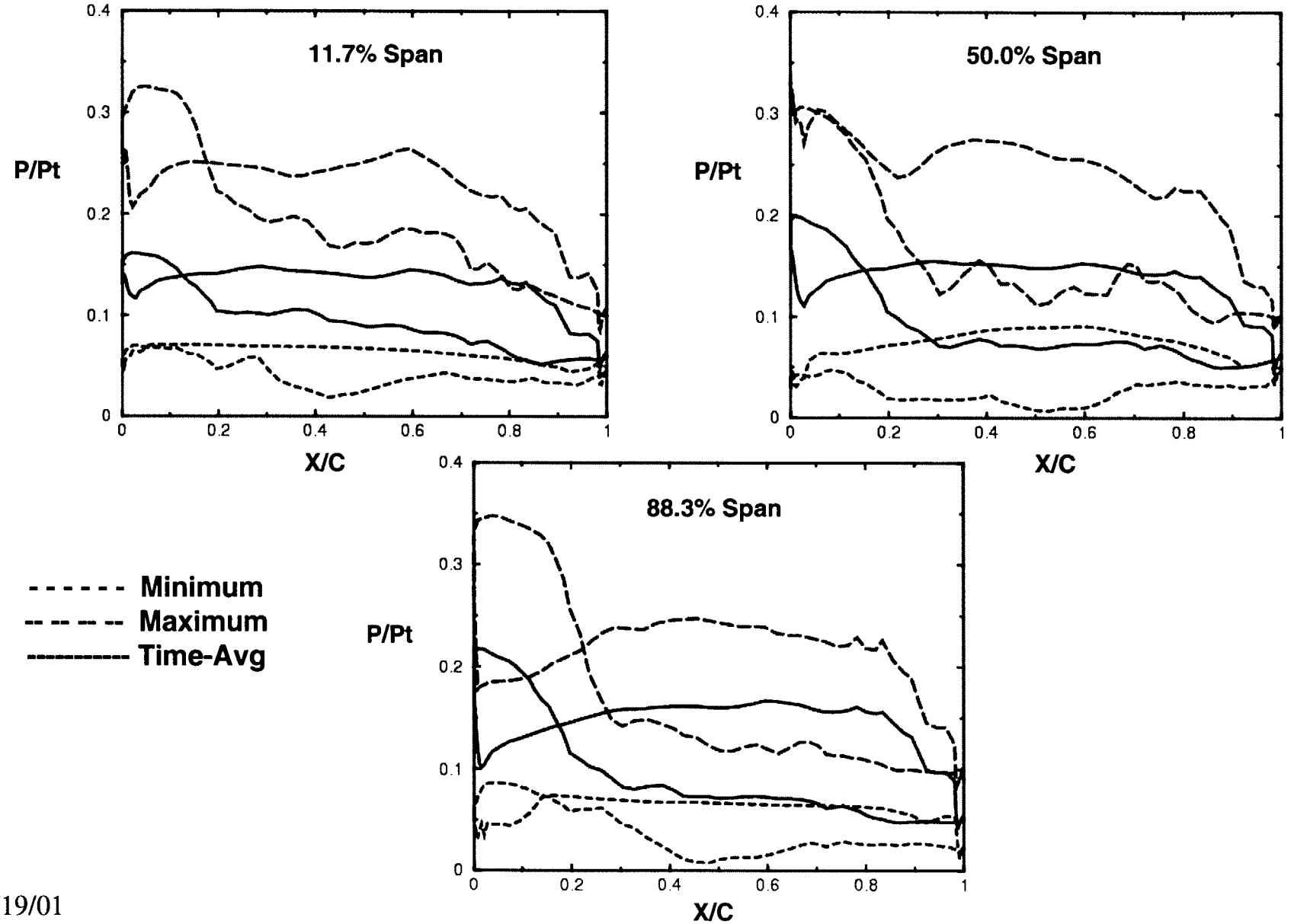


Instantaneous Mach Number - 60% Span

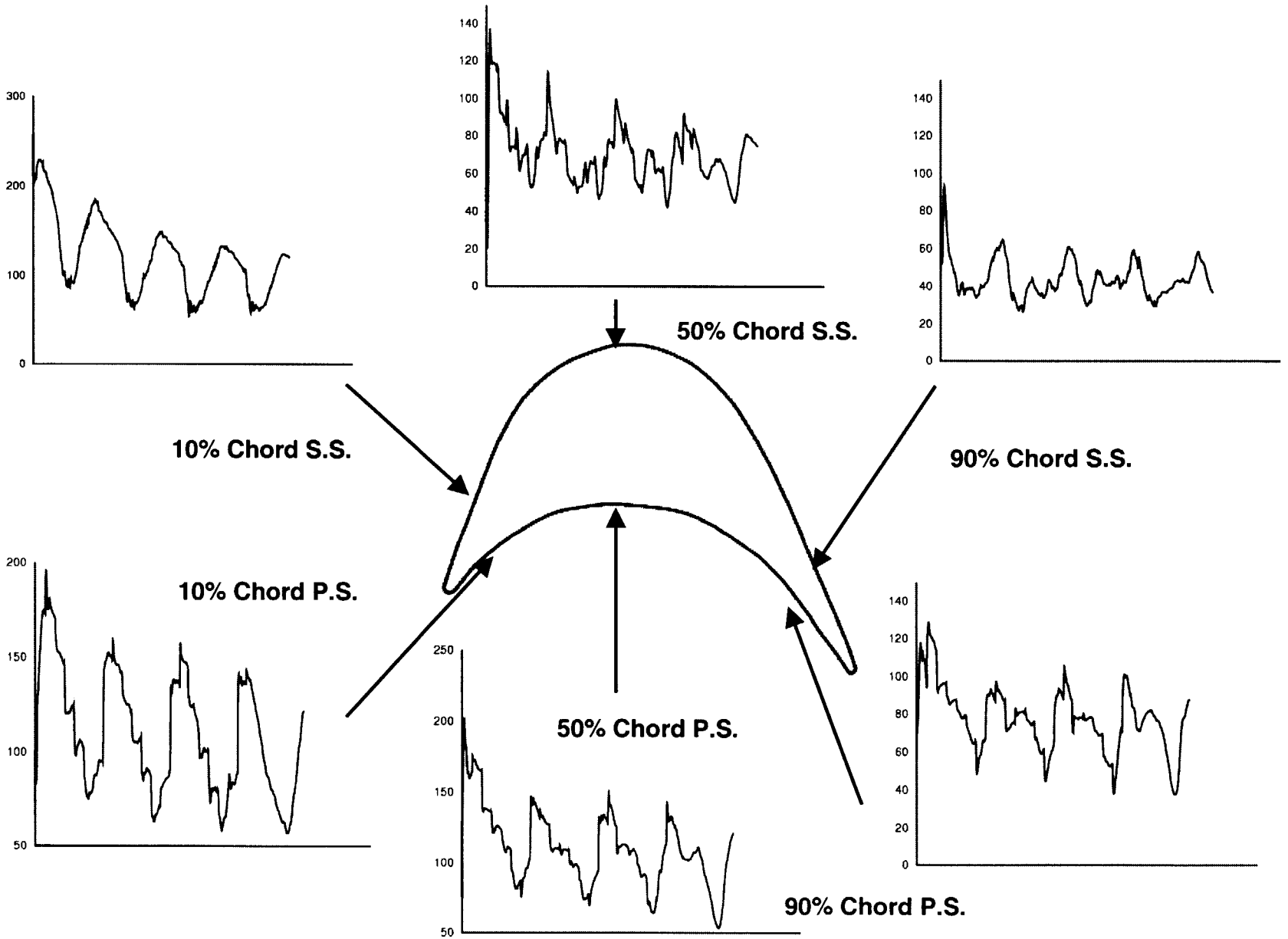
Instantaneous Mach Number - Nozzle



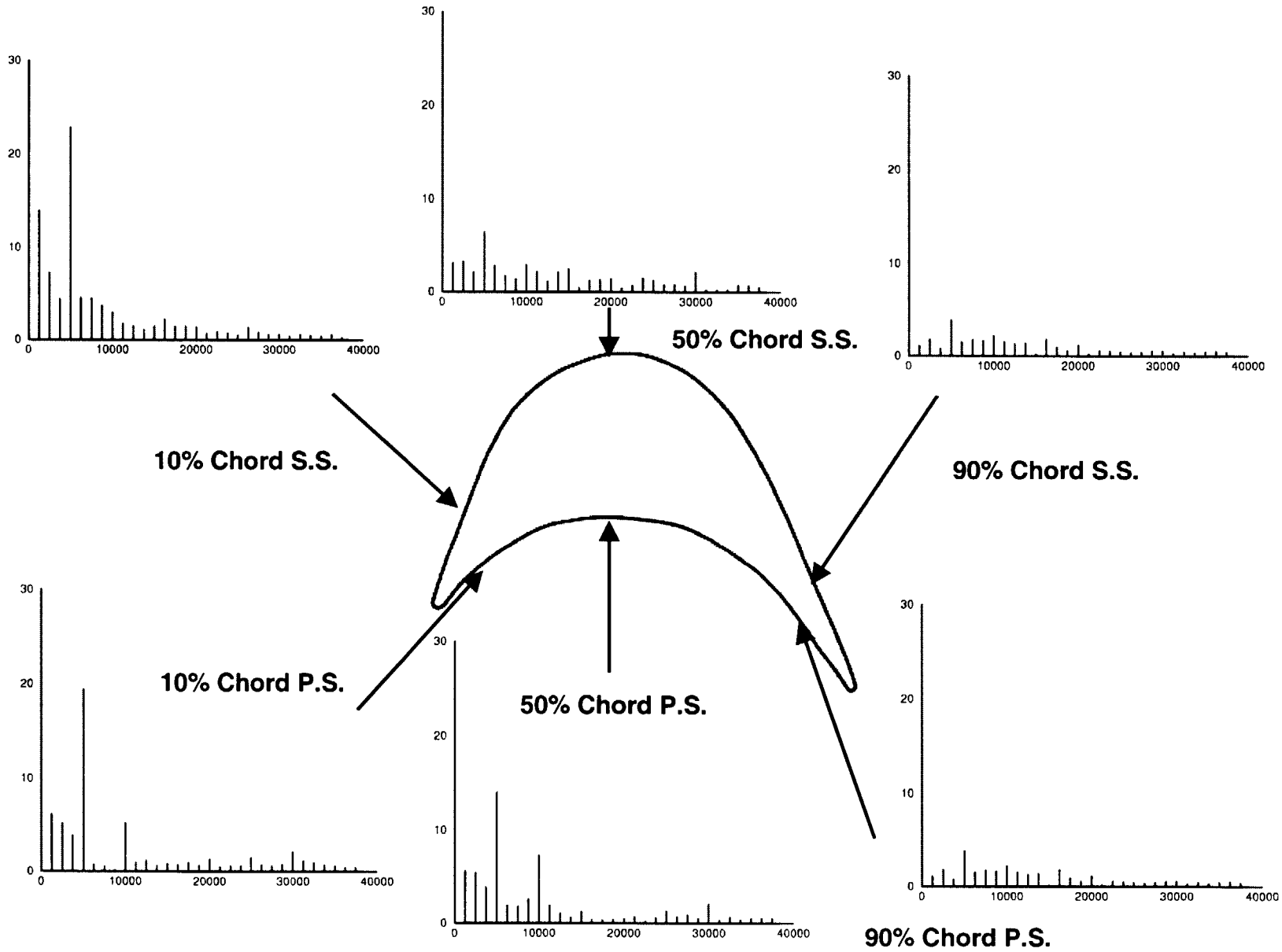
Unsteady Rotor Pressure Envelopes



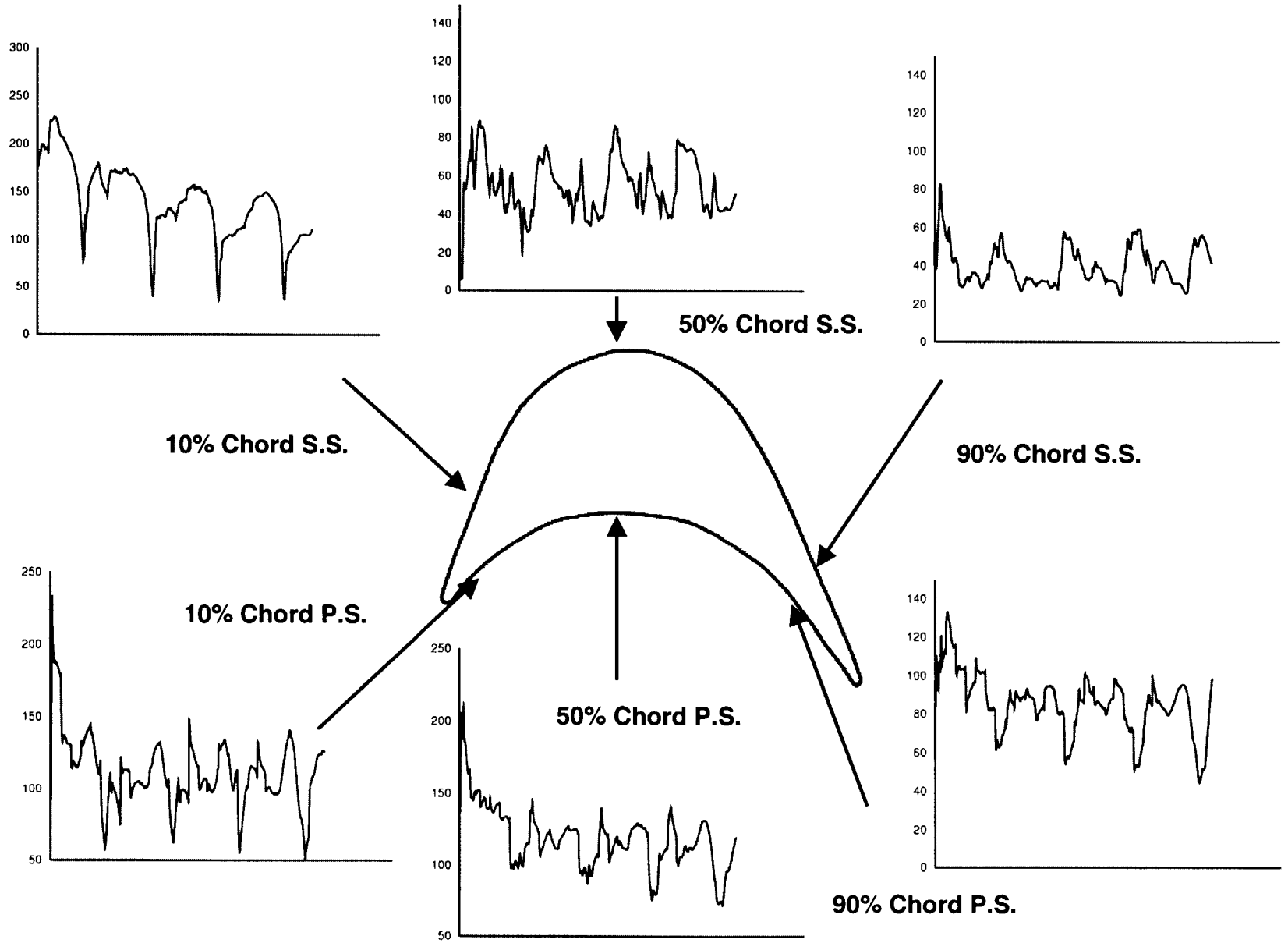
Unsteady Pressure - 11.7% Span



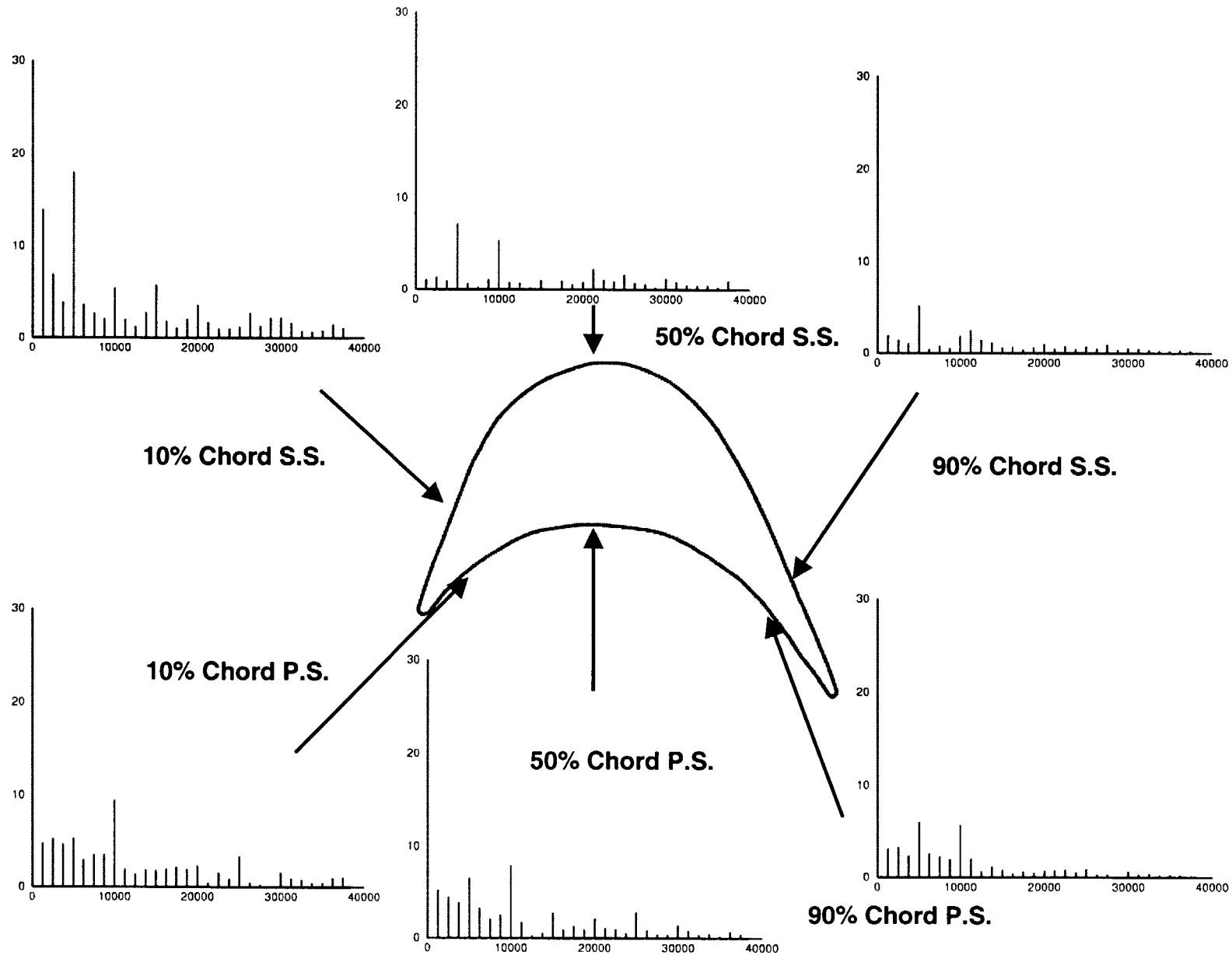
Unsteady Decomposition - 11.7% Span



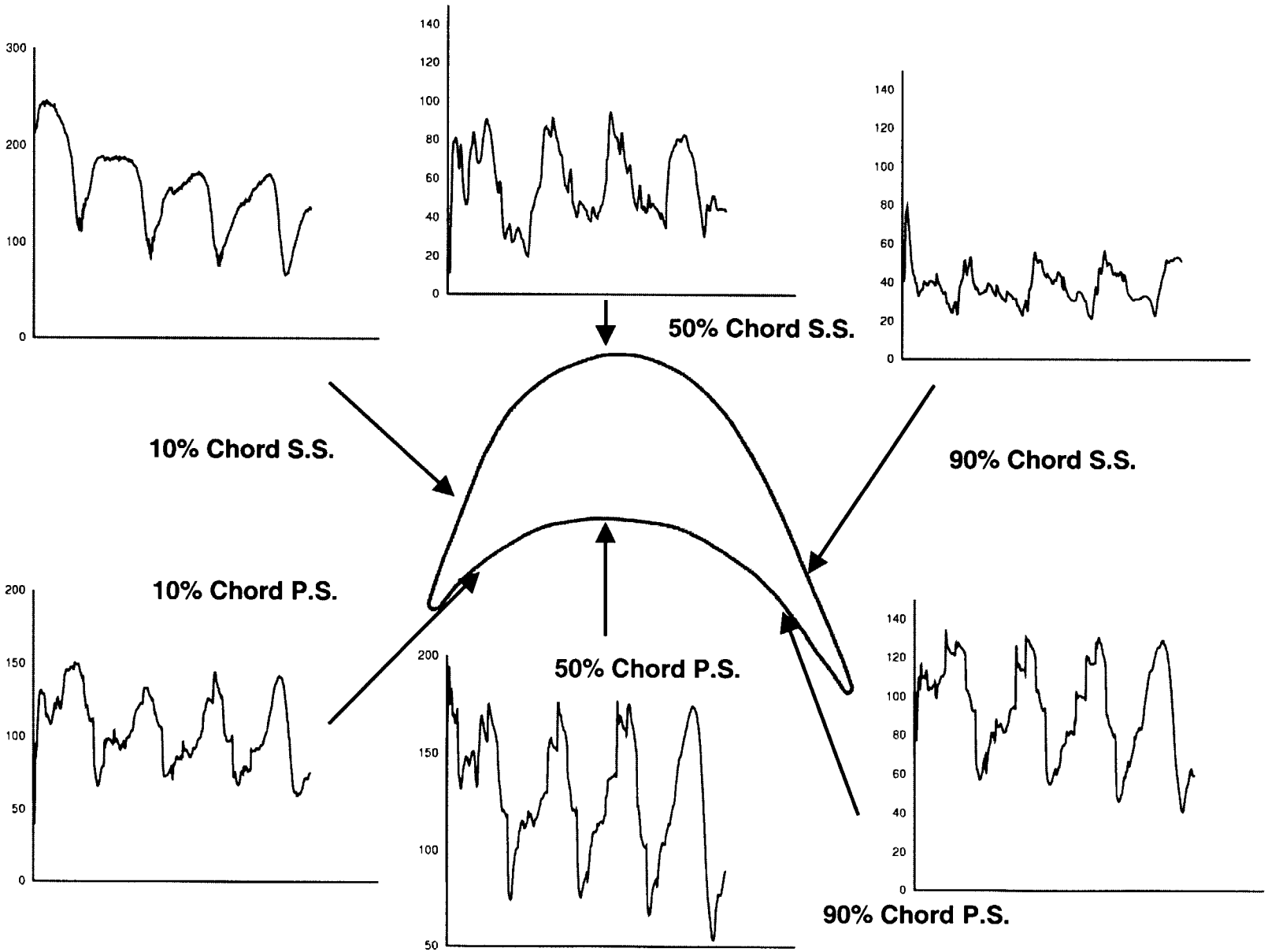
Unsteady Pressure - 50.0% Span



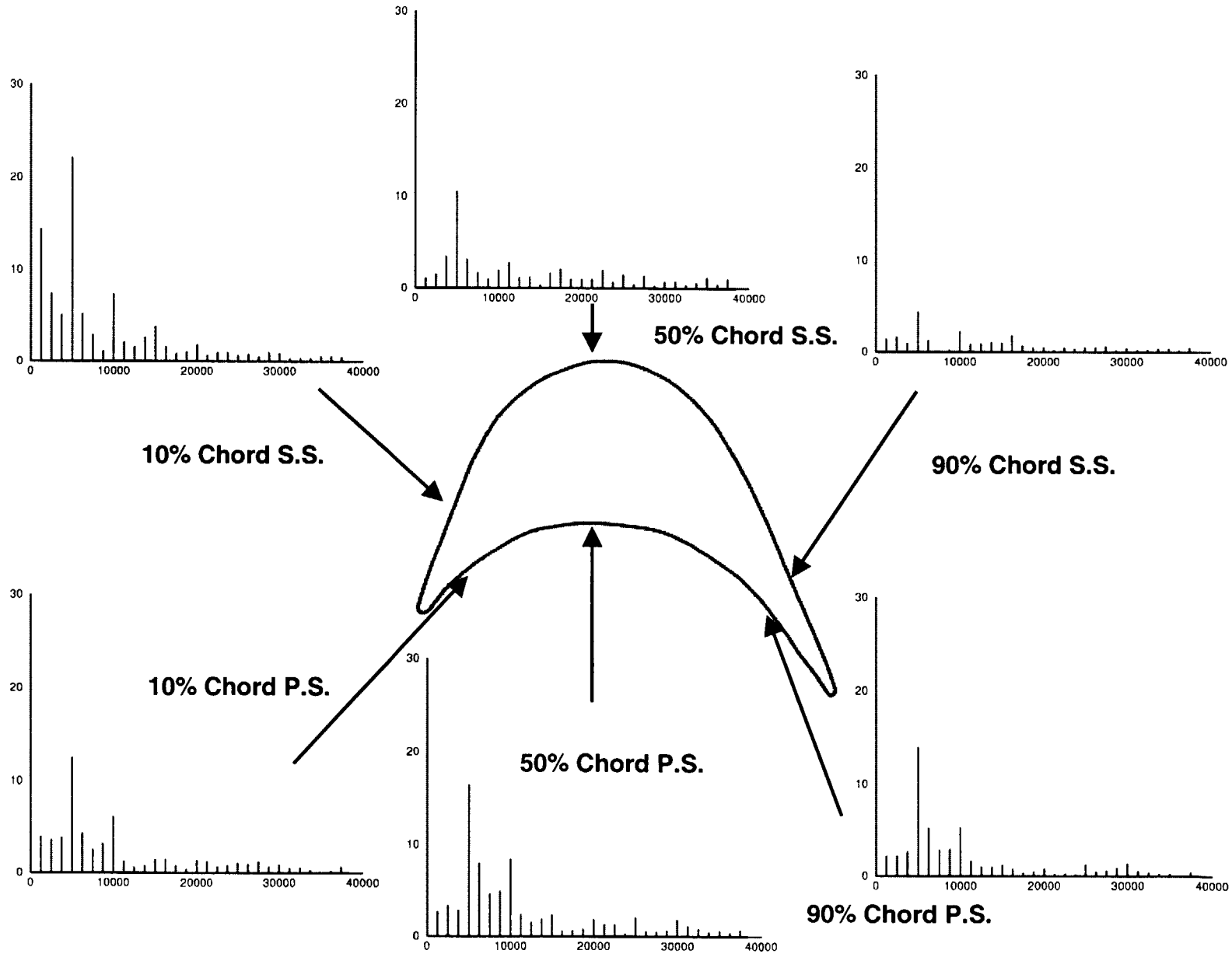
Pressure Decomposition - 50.0% Span



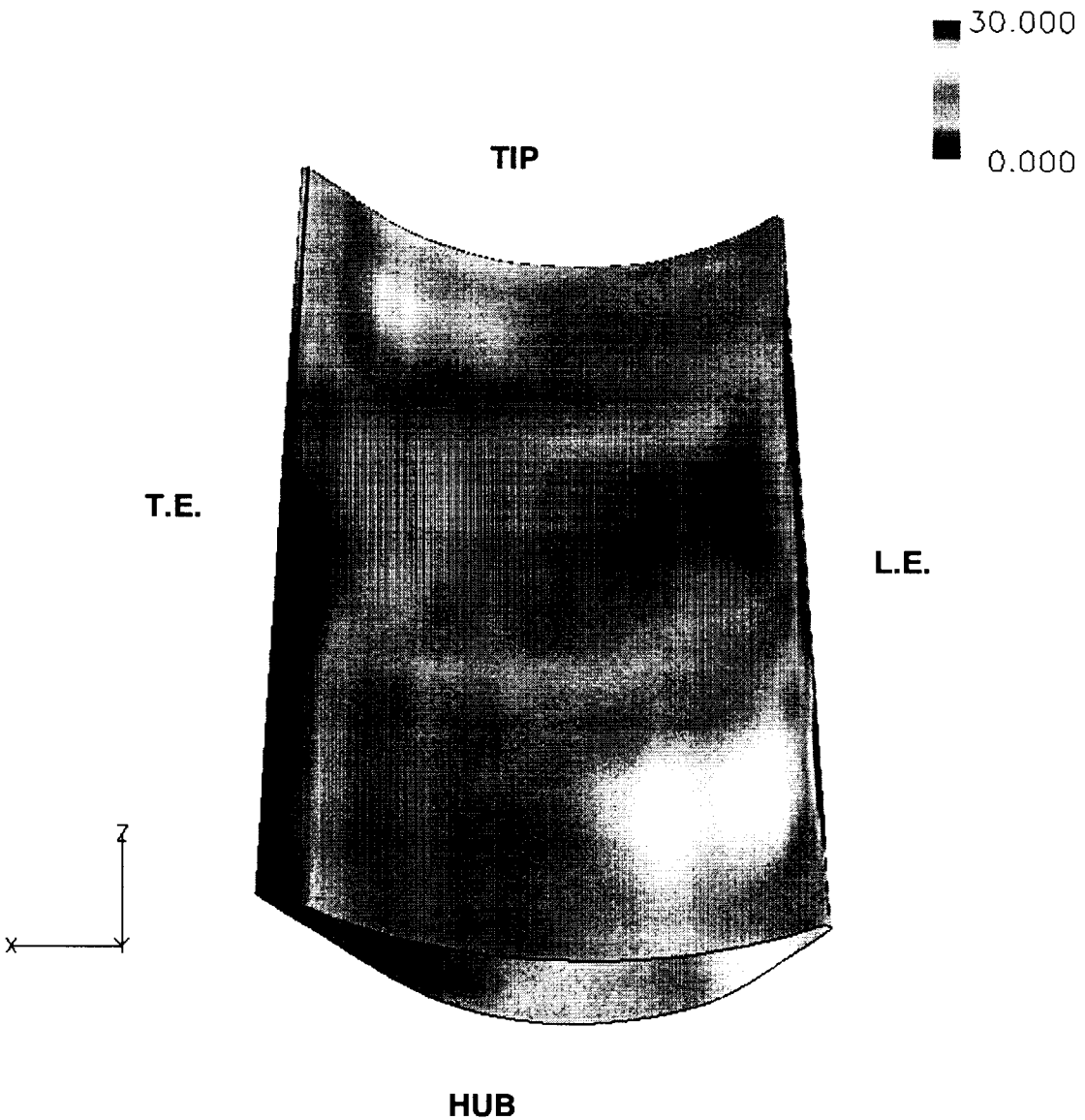
Unsteady Pressure - 88.3% Span



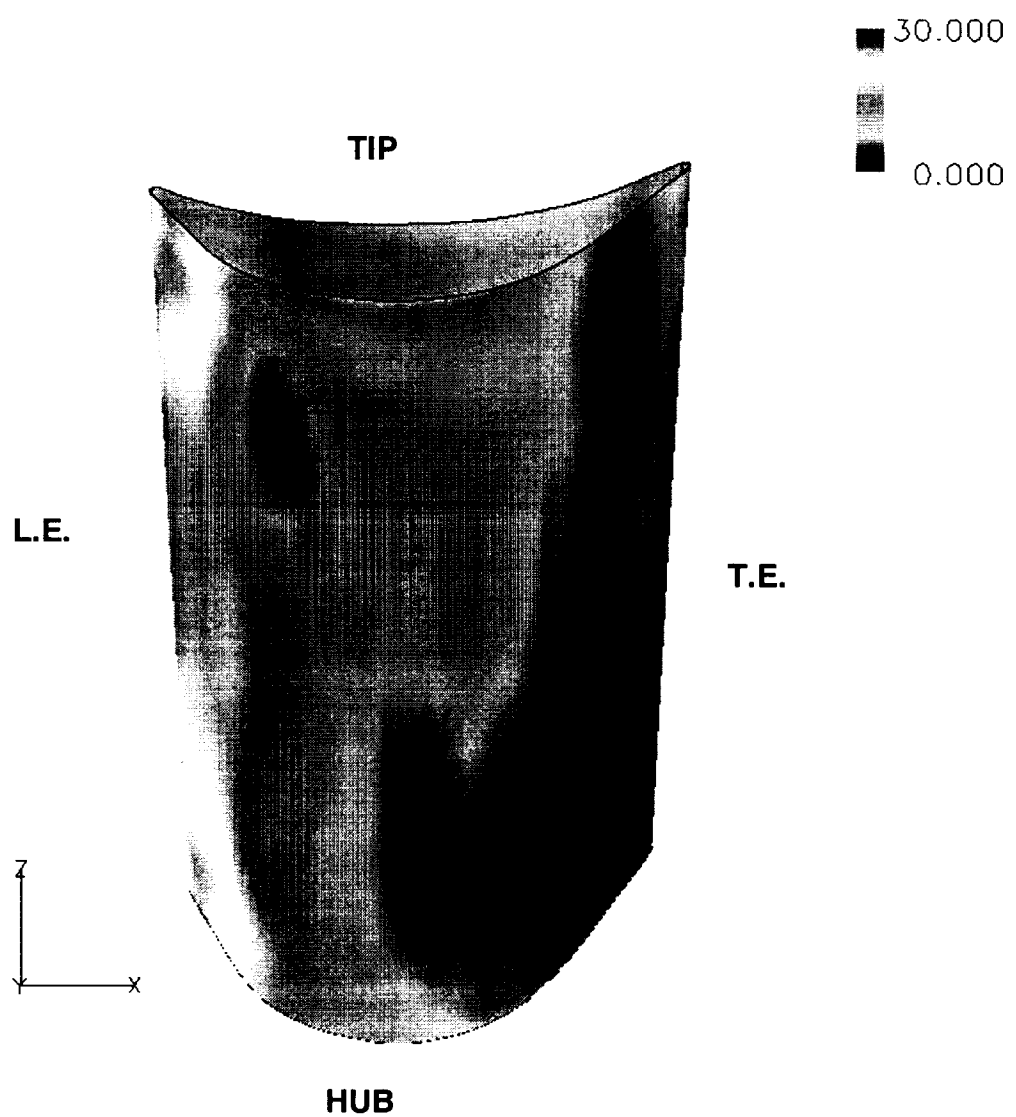
Pressure Decomposition - 88.3% Span



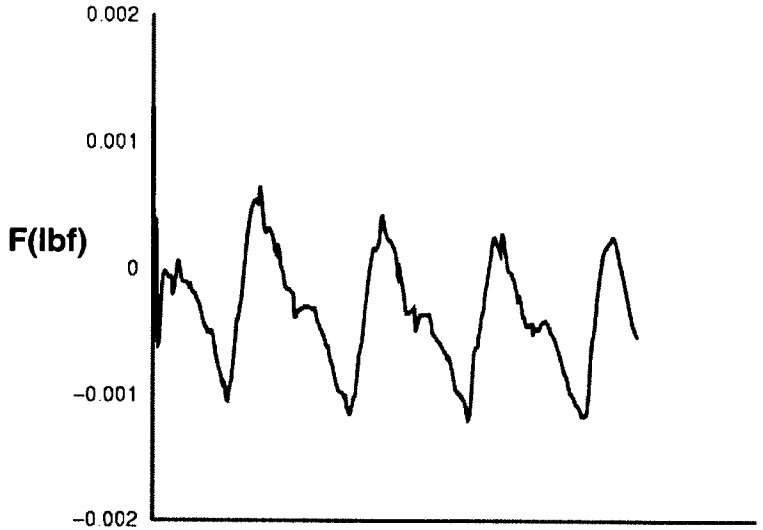
Unsteady Pressure at Nozzle-Passing Frequency - P.S.



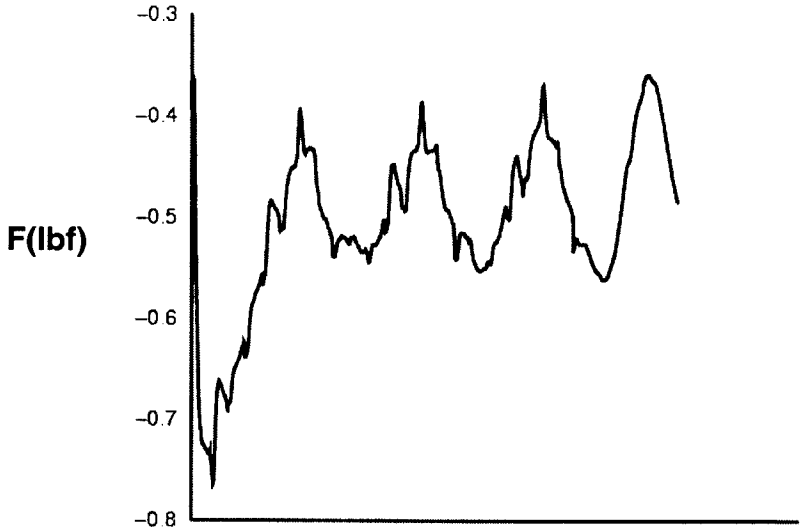
Unsteady Pressure at Nozzle-Passing Frequency - S.S.



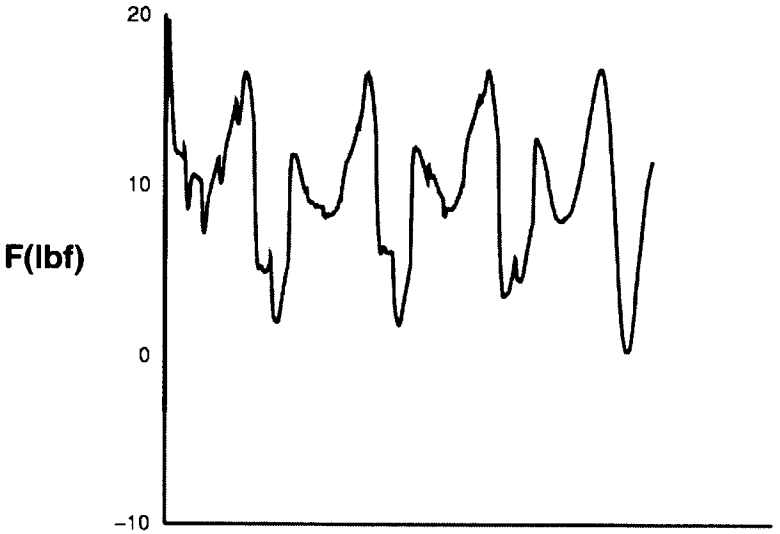
Unsteady Integrated Forces



Axial Force



Radial Force



Tangential Force

Conclusions

- **Full admission simulation performed for the Simplex turbine**
  - models one nozzle and 12 rotors
  - significant unsteadiness at nozzle-passing frequency on the rotor suction surface; especially in the endwall regions (due to the nozzle jet)
  - additional unsteadiness on the suction surface at half the nozzle-passing frequency
  - significant unsteadiness at twice the nozzle-passing frequency on the rotor pressure surface (indicating the presence of reflected waves)
- **Partial admission simulation underway for Simplex turbine**
  - models all nozzles and rotors
  - multiples revolutions must be run to determine effects of nozzles intermittently passing between flow and no-flow regions